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DETERMINATION OF VISCOSITY OF WILD MANGO (*Irvingia gobonensis*), HIBISCUS (*Rosa sinensis)* AND OKRO (*Abelmoschus esculentus)* AT DIFFERENT TEMPERATURES

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ABSTRACT

Viscosity is an important factor in fluid transport. It is a quantity that influences flow properties of fluid and quite useful food product designs. This study is aim at determining the viscosity of selected plant based materials, Wild mango, Hibiscus and Okro and to obtain a viscosity temperature model necessary to predict viscosity of these materials at various temperature values. The viscosity of these materials were determined using the volume flow rate method at a temperature range between 299k to 383k and the viscosity temperature model obtained from an empirical relationship. Wild mango exhibited the highest value of coefficient of viscosity at all temperature range with values between 18.3 x $10^{-3}NSm^{-2}$ to 5.45 x 10^{-3} NSm^{-2} while Hibiscus and Okro have values of coefficient of viscosity ranging between 6.69 x $10^{-3}NSm^{-2}$ to 1.82 x 10^{-3} NSm^{-2} and 8.05 x $10^{-3}NSm^{-2}$ to 2.10 x 10^{-3} NSm^{-2} respectively. The coefficients of viscosity of these materials were found to decrease with increase in temperature. *The viscosity temperature model obtained for wild mango, Hibiscus and Okro are* $\mu_w = 0.91\times10^{-3}T^{-5.39}$, $\mu_H = 3.85\times10^{-3}T^{-4.56}$ *and* $\mu_K = 15\times10^{-3}T^{-3.23}$ *respectively*

KEY WORDS: *Viscosity, temperature, Wild mango, Hibiscus, Okro*

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1. INTRODUCTION

Viscosity is a fundamental quantity that determines the flow properties of fluids. It is defined as a quantitative measure of fluid resistance to flow. It is an internal friction which resists the sliding fluid layers moving over each other [1]. The viscosity of liquids occurs primarily due to the cohesive forces existing between the molecules of the fluid. Highly viscous fluid will not pour or spread out easily as fluid with lesser viscosity. Knowledge of viscosity of materials is required in the design of food products because the resistance of food products to flow is critical to processing, pumping, filling and moulding of the food products. It also affects product properties such as mouth feel, pour ability, cling, emulsion stability and ease of swallowing [2, 3]

. Several studies on the viscosity of vegetable oils and effect of temperature on it have been undertaken by different researchers [4, 5, 6]. Reports also exist on the study of viscosity of fruit juice. It has well been reported in literatures that temperature has a strong effect on the viscosity of fluid products where it found that viscosity decreases with increase in temperature and a viscosity- temperature relationship has been developed [7].

In this work the viscosity of some local plant materials that are viscous at aqueous state and effect of temperature variations on their viscosity are evaluated.

II. MATERIALS

The materials considered are Wild mango (I*rvingia gobonensis*), Hibiscus (R*osa sinensis)* and Okro (A*belmoschus esculentus).*

(i). Wild Mango (*Irvingia gobonensis*)

Wild mango is considered as a multipurpose fruit tree in India because it provides food, fuel, fiber and timber in the country [8]. This fruit contains seed known as the kernel with oil. The oil is highly nutritive and used for bakery, production of cosmetics, dikka fat, chocolate and soap [9]. In South- south Nigeria it is used as thickening agents in soup and stew and also as flavoring agent [10]. Wild mango is identified with many local names in African countries such as dika nut, egili (Igala, Nigeria), Oghi (Etsako, Nigeria), African mango [11] others are Mbukpap Uyo (Ibibio, Akwa Ibom State, Nigeria) and Ogbonor (Ibo speaking Nigerians) and bush mango (India). *Irvingia gbonensi*s are commonly found in the tropical rain forest of Nigeria, Cameroon, Congo, Ivory Coast [12, 13]. The wild mango are reported to appear in different colours, green, greenish yellow, Yellow, Brownish yellow and reddish yellow [14] .

To extract the kernel the fruit is allowed to ferment and sundried after which the endocarp is cracked open and the kernel (cotyledons) are extracted and kept in a dry place. The nutritive value of the fruits, the kernel seed, physicochemical properties and aroma content of the Bush mango are reported in the literature [9, 10]

(ii) Hibiscus (*Rosa sinensis L.*)

Hibiscus is an ornamental plant commonly planted in gardens and compound in Nigeria. It has dark red coloured flowers and green leaves [15]. It is reported that it has a high nutritive and medicinal values [16, 17]. In China it is reported that the dye is used for foods and liquors. In Akwa Ibom State, Nigeria, Hibiscus leaves are used as food, beverages, soup thickening agent, tea, spices, sauces and as medicine as also applied elsewhere [18]. The Hibiscus leaves are also use as mild laxative, expectorant, diuretic [19] the aqueous ethanolic extract of *Rosa senensis* aerial part is used in cure of constipation and diarrhea [15]

(iii). Okro (*Abelmoschus esculentus*)

Okro is one of the vegetables that are viscous in aqueous state. It is commonly found in the tropical region which includes Nigeria. Okro exhibits a gum like nature in its aqueous state and usually used in soup making. The gum-like nature of this food thickening material is as a result of the presence of a chemical substance known as glycan [20]. It is reported to be rich in energy, protein, niacin, ascorbic acid and vitamins [21]. It is also known to contain linoleic and oleic acids. The linoelic acid consists of two conjugated double bonds while oleic acid consist of a single double bond which are being affected by temperature [22, 23]

III. SAMPLE COLLECTION AND PREPARATION

All the materials were purchased fresh from a local market in Uyo, Nigeria and stored in polythene bags. All foreign materials on the samples were removed by washing with distilled water. Each of these materials was grounded to form paste using electric blender and 100g of these materials was mixed with 1000ml of distilled water, stirred to dissolve and form solution. The solution was filtered and smooth gel obtained for the experiment. Relative densities of the solution were measured using the specific gravity bottle according to [24]. The diameter of the capillary tube was measured with vernier calipers. The solutions used for the experiment was maintained at constant temperature at each time of measurement using Marriott tank. The

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starting temperature was 298k (25^0C) and varied in steps of 20 ^{0}C to 358 k (85^0 C). The viscosity of each of the materials was evaluated at these varying temperatures respectively. In the evaluation, two fundamental theories were employed in the evaluation.

IV. THEORITICAL BACKGROUND

(i) **The volume flow rate method (Hazen-Poiseulli's theory)**

Suppose a solution of coefficient of viscosity (μ) flows steadily through a capillary tube of diameter (a) and length (L) thus creating pressure (P) at the pressure head (H). The volume flow rate Q is given as [25]

$$Q = \frac{\pi P a^4}{8\mu L} \quad (1)$$

Let $$P = g\rho H \quad (2)$$

Where ρ is the density of the solution and g is the acceleration due to gravity

Then $$Q = \frac{\pi a^4 g\rho H}{8\mu L} \quad (3)$$

or $$\mu = \frac{\pi g\rho a^4}{8L} \; \frac{\Delta H}{\Delta Q} \quad (4)$$

$$R = \frac{8\mu L}{\pi a^4} \quad (5)$$

μ is the coefficient of viscosity and R is known as the flow resistance of the solution

(ii) **Viscosity- temperature modeling**

The viscosity- temperature function is given as a power law [26]

$$\mu = aT^b \quad (6)$$

T is the absolute temperature. The constants a and b are obtained from a plot according to equation 7

$$\ell n\mu = \ell na + b\ell nT \quad (7)$$

V.RESULTS AND DISCUSSION

The determinations of the coefficient of viscosity of different materials are reported in literatures by many authors. This is because of its effect on the flow rate, absorption and drainage rate of materials and its consequences when applied in production procedures. The need to consider the effect of temperature on the viscosity of these materials is also paramount because heating of these materials could be necessary during production process. In this study, chemical composition of the materials were not analysed, however it is known that the viscous nature of these materials is due to the presence of a chemical substance known as glycan.

(i) The Volume flow rate

The volume flow rate (Q cm^3/s) at different pressure heads (H cm) were studied at a temperature of 333k (60^0C) for the three materials are results presented in Table 1.0. it was also observed that the flow times were different at the same temperature. Equally observed was that as the pressure heads increases, the flow rate of all the solutions also increases. Density of the materials were also considered in this study, as it is known to be an important factor which influences the absorption and drainage rate of materials [5]. The measured density of the studied material shows that wild mango (*Irvingia gobonensis*) has a density of 1.041 x 10^{-3} Kg/m^3 while Hibiscus and Okro recorded 0.996 x 10^{-3} Kg/m^3 and 0.972 x $10^{-3}$$Kg/m^3$ respectively at a temperature of 298 K (23^0C). It was observed that the density of these solutions were linearly dependent on temperature. However the variations in the densities of these materials at the various temperature considered in this study were minimal as the difference in the temperature range was small between 10^o C (283K) to 27^o C (290K).

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Table1. Volume flow rates for the investigated materials at temperature of 333 k

	Q (cm³/s)		
H (cm)	Wild mango (Qw)	Hibiscus (QH)	Okro (Qk)
12.0	0.11	0.50	0.45
13.0	0.14	0.62	0.52
14.0	0.19	0.75	0.62
15.0	0.23	0.84	0.70
16.0	0.28	0.95	0.78
17.0	0.35	1.50	0.87
Time (sec)	360.0	250.0	300.0
ρ (g/cm³)	1.014	0.996	0.972
L (cm)	47.60	47.60	47.60

The above Table1.0 shows the volume flow rates of the different solutions with different densities at different pressure heads, flow time, from same capillary tube length at same temperature of 333k (60⁰C).

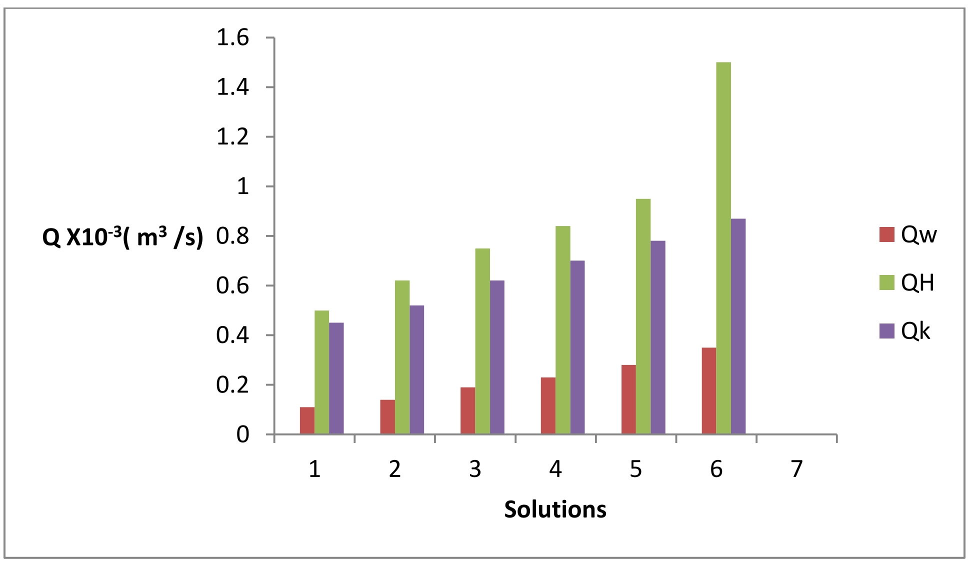

Fig. 1: Comparison of the volume flow rate of the investigated materials at 333k

The comparison of the volume flow rate for all the solutions are presented in Fig. 1 where it is seen that at all pressure heads hibiscus exhibited the highest flow rate with wild mango being the least. Similarly the flow rate of these materials exhibited the same flow rate at other temperature range.

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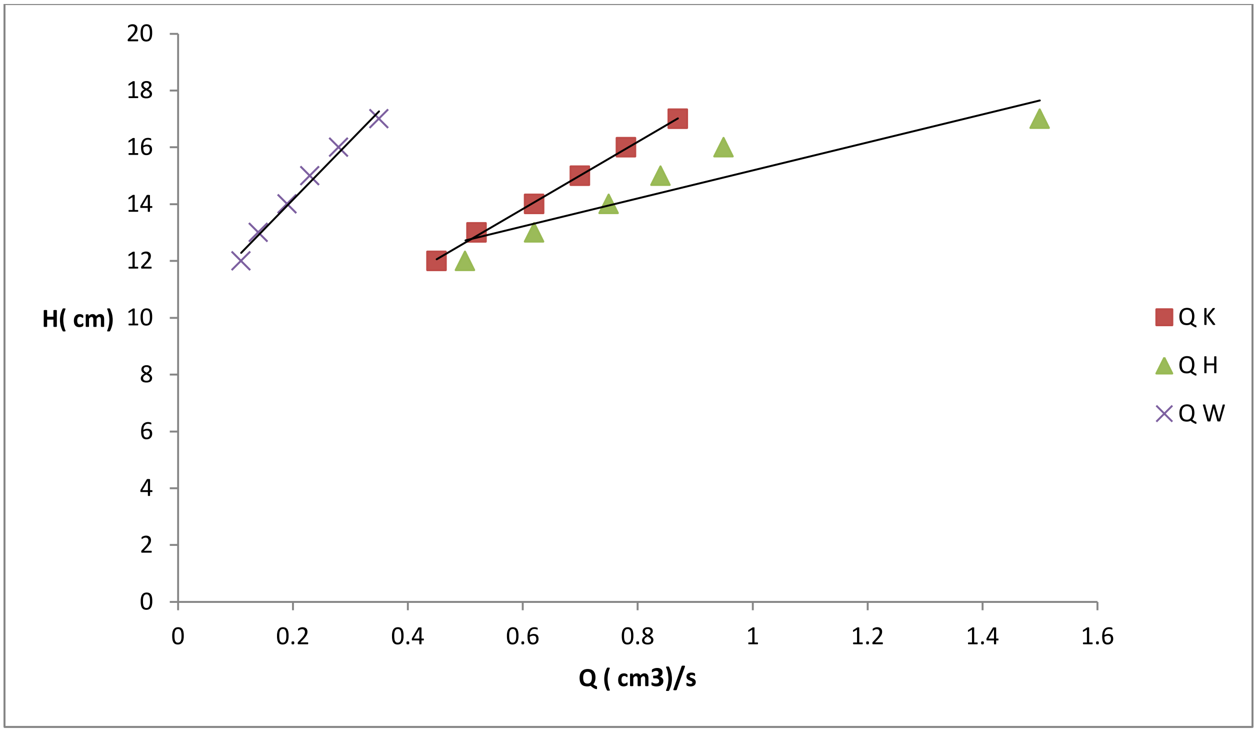

Fig. 2: Volume flow rate of the solutions at 333k at different pressure heads

Figure 2 shows the volume flow rate of the solutions at a temperature of 333 k at certain pressure heads. The Q_k, Q_H and Q_w are the flow rates for okro, hibiscus and wild mango solutions respectively. From the regression of the lines in Fig. 2 above, the coefficient of viscosity of the viscous solution are determined by fitting the slope into equation 4. Similar procedures for obtaining the viscosity were undertaken for the solutions at temperatures 299k, 306k and 359k, 373k and 383k and results recorded in Table 2.0.

Table 2: **Variation of viscosity with absolute temperature.**

$\mu \times 10^3 NSm^{-2}$			
Temp K	Wild mango	Hibiscus	Okro
299	18.13	6.69	8.05
306	13.19	5.18	6.98
333	8.99	3.52	3.98
359	7.52	2.35	2.75
373	6.60	2.01	2.43
383	5.45	1.82	2.10

Viscosity - temperature modeling

Analysis of the variation of coefficient of viscosity with absolute temperature (Table 2) shows that viscosity of these solutions decreases with increase in temperature similar to results of other studies. Wild mango (*Irvingia gobonensis*) was found to have the highest value of coefficient of viscosity at all temperature range between 18.3 x $10^{-3}NSm^{-2}$ to 5.45 x 10^{-3} NSm^{-2} than others, this could be due to the fact that wild mango was denser than hibiscus and Okra. Hibiscus (*Rosa sinensis)* and Okro (*Abelmoschus esculentus*) had value of coefficient of viscosity of 6.69 x $10^{-3}NSm^{-2}$ to 1.82 x 10^{-3} NSm^{-2} and 8.05 x $10^{-3}NSm^{-2}$ to 2.10 x 10^{-3} NSm^{-2} respectively. Although Okro was denser than hibiscus at 299 K however, it was observed that at high temperature the hibiscus solution become less viscous than Okro. It is reported in the literature that viscosity of oil and fatty acids which are some contents of the studied materials governs the absorption and drainage rate of these materials. Consequently the higher the viscosity of the material the slower the absorption and drainage rate of the material [27]. It is important that the influence of

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temperature on the viscosity of materials be evaluated at different temperatures values to give valuable information on the effect of temperature variation on the flow rate of these materials and could guide the manufactures of medicine and other products that utilizes these materials. Viscosity-temperature correlations can give an understanding of the flow behavior of these materials at different temperatures. The viscosity temperature relationship is shown in Fig. 3 and the models for the calculation of viscosity values at variable temperatures is developed using equation 7 while the constants a and b are obtained through a plot of equation 7 as shown in Fig. 4

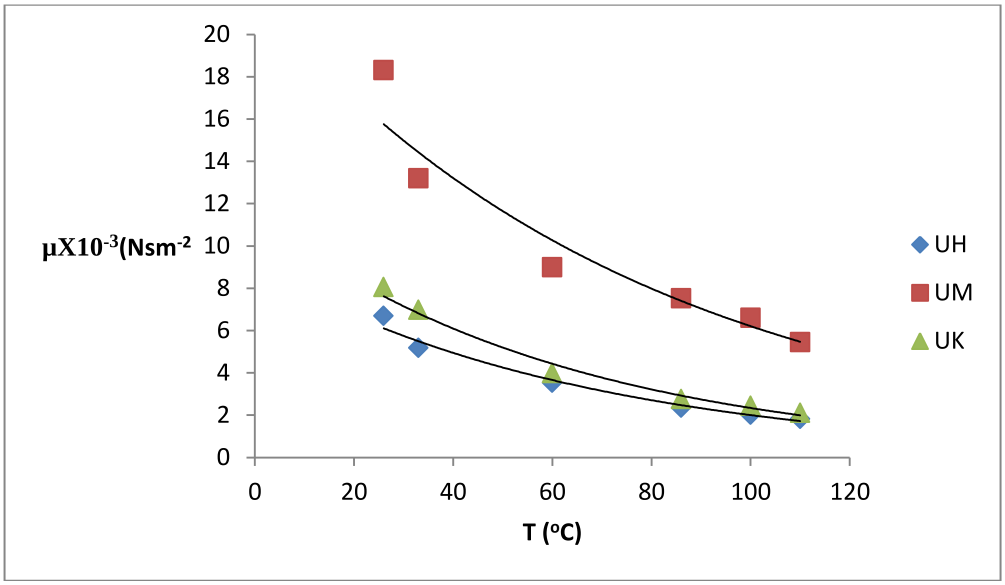

Fig. 3: The coefficient of viscosity of investigated materials as a function of temperature.

The linear plot of Fig.3 to obtain the constants in equation 7 is presented in Fig. 4

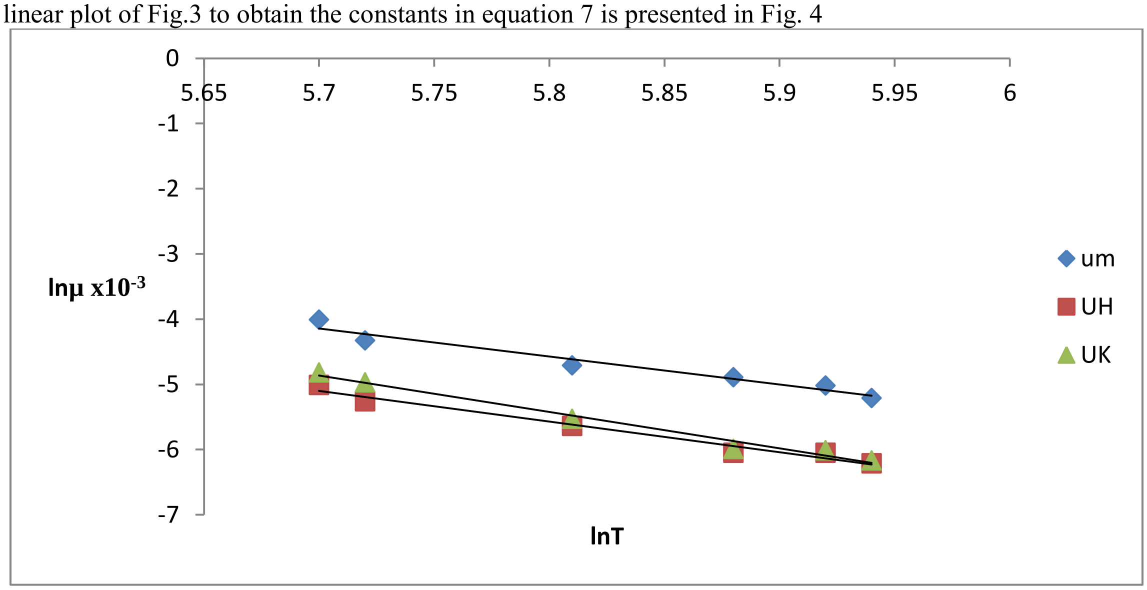

Fig. 4: The relationship of the dynamic viscosity and elevated temperatures

The constants a and b are obtained from the regression analysis of the line of best fits in Fig. 4 and presented in Table 3

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Table 3: Calculated values of constants a and b in equation 6

Materials	$a \times 10^{-3} (Nsm^{-2})$	b ($Nsm^{-2}K^{-1}$)
Wild mango	0.91	-5.39
Hibiscus	3.85	-4.56
Okro	15.0	-3.23

To predict the viscosities of these biodiesels at various temperatures, the constants a and b are fitted into equation 6 to obtain equations 8, 9 and 10.

$$\mu_w = 0.91 \times 10^{-3} T^{-5.39} \quad (8)$$

$$\mu_H = 3.85 \times 10^{-3} T^{-4.56} \quad (9)$$

$$\mu_K = 15 \times 10^{-3} T^{-3.23} \quad (10)$$

Where μ_W, μ_H, μ_K are coefficient of viscosity of wild mango, Hibiscus and Okro respectively.

VI.CONCLUSIONAND RECOMMENDATION

Viscosity is seen to be affected by elevated temperature in a such a way that as the temperature of the materials rises, their viscous level decreases as corroborated by reports of various studies of other materials like vegetable oils, non-edible oils and oils used in biodiesel production.

The mathematical models developed can be used in predicting the variation of viscosity with elevated temperature, especially when these materials are considered for production of medicine and other food products.

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